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Mortality of Juvenile Brown Shrimp *Penaeus aztecus* Associated with Streamer Tags[1]

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Abstract

Immature brown shrimp were marked with plastic streamer tags, then observed in large tanks for the effect of tags on mortality under a variety of pre- and post-tagging treatment regimes. Except where tagged animals were held at low density (9 animals/m^2) and with few untagged conspecifics (2/m^2), mortality was about 50% higher among tagged animals than among untagged controls. Differences among treatment groups in the number of handling steps, the wound caused by the tagging needle, the duration of high-density holding prior to release, and the sex of test animals were independent of mortality. The identity of the tagger and the size and condition of animals selected for tags were associated with small differences in survival in certain trials. Evidence from direct observation and from damage to tags suggested that mortality was higher among tagged animals because tags evoked attacks from untagged conspecifics and (in one trial) fish. In light of contrary evidence from some earlier studies, the clearer water and greater holding density in our study may have promoted tag-induced mortality by increasing the probability of interactions among animals.

Though it is intrinsically difficult to make a permanent mark on an animal such as a crustacean that periodically sloughs an external skeleton, the commercial importance of the penaeid shrimp fisheries in the Gulf of Mexico has justified an intensive mark–recapture program. Early tagging methods for shrimp, including intramuscular dyes and pigments, internal tags, and Petersen tags, have been abandoned in favor of soft plastic streamer tags inserted between the first and second abdominal segments (Marullo et al. 1976). Compared with the marking methods it replaces, the streamer tag apparently produces few post-insertion complications, interferes little with the behavior of tagged shrimp, and does not confer an increased risk of mortality under certain test conditions (Marullo et al. 1976; Johnson 1981).

Disappointing tag returns for some release programs, however, have raised questions about the possibly deleterious effects of streamer tags. Recoveries of tagged shrimp from five of the six releases in Texas inshore waters during 1978 and 1979 have been "virtually nil" (Cody and Avent 1980). For example, of 27,324 tagged animals released near Port Aransas, Texas, in June 1978, only one was recovered by the end of September 1979 whereas 839 floating tags washed ashore on nearby beaches within 10 days of the release. Cody and Avent (1980) hypothesized that predators were attracted to tagged animals. Other private theories to explain poor recoveries have been advanced, most invoking uncontrolled or uncontrollable differences in tagging methods or in the condition of animals prior to tagging. In the present study, we examined potential effects of tagging method, shrimp condition, predators, and post-release animal density on the mortality of tagged juvenile brown shrimp under conditions that approximate those of a clear-water Texas estuary.

Methods

Juvenile brown shrimp were captured during June and July 1980 by a commercial bait shrimp trawler in Offat's Bayou Channel, Galveston Island, Texas. They were held at the bait dealer's (Johnnie's Bait Camp) for no more than 6 hours in a shaded outdoor tank that continuously received seawater from Offat's Bayou. Water temperature in those holding tanks reached a maximum of 32.1 C on 30 June 1980, when dissolved oxygen was 5.4 mg/liter. The animals were transferred to holding tanks at the

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Galveston Laboratory in insulated 50-liter containers with approximately 6 animals per liter of continuously aerated seawater. Laboratory holding tanks contained 500 liters of aerated, flowing seawater and no more than 1 animal per liter. Animals ranged in tail length (tip of telson to posterodorsal carapace margin) from approximately 30 mm to 77 mm; those used for experiments were at least 41 mm in tail length. In this species a tail length of 50 mm corresponds to an approximate total length (rostrum to tip of telson) of 85 mm. Except for one treatment group in a stress experiment (see below), only animals that lacked markedly opaque necrotic foci in abdominal musculature, a sign of anoxic stress (Rigdon and Baxter 1970), were chosen for experiments.

Animals were tagged by experienced staff of the Galveston Laboratory, National Marine Fisheries Service, who were not informed of specific experimental objectives. Tagging was performed according to current standards with green polyethylene mini-ribbon tags (Floy Tag and Manufacturing Company, Seattle, Washington) inserted through the abdomen between the first and second abdominal segments, accompanied by antibiotic prophylaxis (Marullo et al. 1976). Tagging was accomplished between 1300 and 1600 hours on the days that each experiment began. Defective tags caused the numbers of animals in treatment groups to differ slightly in two experiments.

Tagged and untagged control animals eventually were released into one of two large outdoor fiberglass tanks for observation. Each tank was colored black on its interior surface, filled with 8 cm of crushed oyster shell beneath 8 cm of 3-mm-screened masonry sand, and fitted with air-operated substrate filters, the angled outlets of which established a slow, circular current in 43 cm of seawater. Tank 1 was a 6.1-m-diameter (29.2 m^2 area) round tank. It received a continual input of seawater at a rate of 1 tank volume in 3 days. Tank 2 was a rectangular raceway tank, 2 m wide by 6.1 m long, built with semicircular ends (15.3 m^2 total area). Tank 2 was fitted with a plate separator and trickle filter, but received no water exchange during experiments. Neither tank showed obvious signs of altered water chemistry (color, odor, algal blooms) during experiments. Both tanks were shaded by translucent plastic. Experimental animals received daily approximately 20% of their aggregate volume of a mixture of equal parts chopped frozen squid and fish flesh. In each experiment, observations for mortality were made at release into either large tank and were repeated daily at 1000 hours. In two experiments, an extra observation was added at 1500 hours on the day after release. At each observation, dead animals and free tags were removed from the tank. *G*-tests (Sokal and Rohlf 1969) were used to test frequencies for independence of treatments.

Four experiments were performed. Each differed from the others in purpose, design, and some methodological details.

Tagging Methods

One experiment was designed to compare the effects on mortality of two different tagging methods, two different post-tagging holding periods, and four different taggers. A control group of 200 randomly selected animals was transferred to the larger tank (tank 1) upon arrival at the laboratory. Then, 400 animals were tagged by the method now used for Texas inshore releases (Texas method). Each of the four taggers measured, sexed, and tagged 100 animals. Half of the animals tagged by each were held for 4 hours and the other half 15 hours before release into tank 1. An additional 200 animals were tagged by the method now used for releases in Louisiana (Louisiana method). Each of four taggers inserted 50 tags, placing the tagged animals into temporary holding pans from which they were recaptured, measured, and sexed by a different person. Animals tagged by the Louisiana method then were held for 4 hours before release into tank 1. Mortality was monitored for 13 days, after which tagged survivors (but not controls) were recovered.

Stress

Potential effects on mortality of pre-tagging anoxic stress and of stresses associated with the tagging process itself were examined with four groups of 200 animals. One group (handled controls) was measured and sexed but not tagged; a second group (sham-operated) was measured, sexed, then wounded by a tagging needle passed through the abdomen; a third group was tagged by the Texas method. Animals selected for the fourth group had incipi-

TABLE 1.—*Mortality of juvenile brown shrimp tagged with streamers under various experimental conditions.*

Treatment	*N*	Dead	Free tags	Live	Lost
		Tagging methods experiment (13 days)			
Tagged in single step, held 4 hours	200	82	22	90	6
Tagged in single step, held 15 hours	199	86	10	102	1
Tagged in two steps, held 4 hours	200	75	28	93	4
Controls (not held)	200	19		[a]	[a]
		Stress experiment (11 days)			
Tagged, evidence of anoxic stress	199	175	10	12	2
Tagged, unstressed	197	150	16	27	4
Sham-operated	200	58		253[b]	19[b]
Handled control	200	70			
		Predator experiment (8 days)			
Tagged	400	145	95	155	5
Control	275	14		250	11
		Density experiment (8 days)			
Tagged, released at 33 animals/m^2	100	43	13	39	5
Tagged, released at 11 animals/m^2	99	6	5	84	4
Control, released at 33 animals/m^2	25	1		24	0
Control, released at 11 animals/m^2	25	1		24	0

[a] Controls were not recovered at the end of this experiment.

[b] Sham-operated animals could not be reliably distinguished from other untagged animals at the end of this experiment, so data from recoveries are pooled.

ent necrotic foci on abdominal segments 4 or 5 or on the ventral margin of the more anterior abdominal segments. These animals were tagged by the Texas method. After 3.5–5.1 hours in holding tanks, all animals were transferred to tank 1 for 11 days of observation. For this and the preceding experiment, the initial animal density in tank 1 was 27 individuals/m^2.

Predators

To test for effects of a potential predator on tag-related mortality, a group of 400 tagged (Texas method) and 275 untagged, unhandled controls were released into tank 2. That tank had been modified in two ways. First, six clumps of artificial sea grass were regularly spaced on the tank bottom. This artificial grass was made from individual filaments of a polyethylene antichafing rope ("whiskers" manufactured for shrimp trawls), clumped and weighted at one end. The free ends of each clump spread and floated to cover an area of approximately 0.2 m^2. Second, a school of eight Gulf killifish *Fundulus grandis* was introduced into the tank 5 days before the shrimp were released. Fishes ranged in standard length from 6 to 9 cm; none was large enough to consume whole experimental shrimp. Mortality of shrimp was monitored for 8 days, after which tagged and untagged survivors were recovered.

Density

Two groups of animals were held after tagging at different densities to examine the impact of animal density on tag-related mortality. Fish and grass were removed from tank 2, then a net partition was installed across its width, resulting in two compartments with areas of 3.8 m^2 and 11.5 m^2. The partition was braced against the tank sides and extended through the sand substratum and 30 cm above the water level to prevent shrimp from passing between compartments. Of the 250 surviving control animals from experiment 3, 100 tagged (Texas method) animals and 25 untagged, unhandled controls were released without an additional holding period into each compartment. Mortality was monitored for 8 days, after which survivors were recaptured.

Results

Over all experiments, only 2% of the tags were not recovered (Table 1). In experiments where controls were recaptured a mean of 4% of untagged animals were not accounted for. Animals that could not be accounted for were suf-

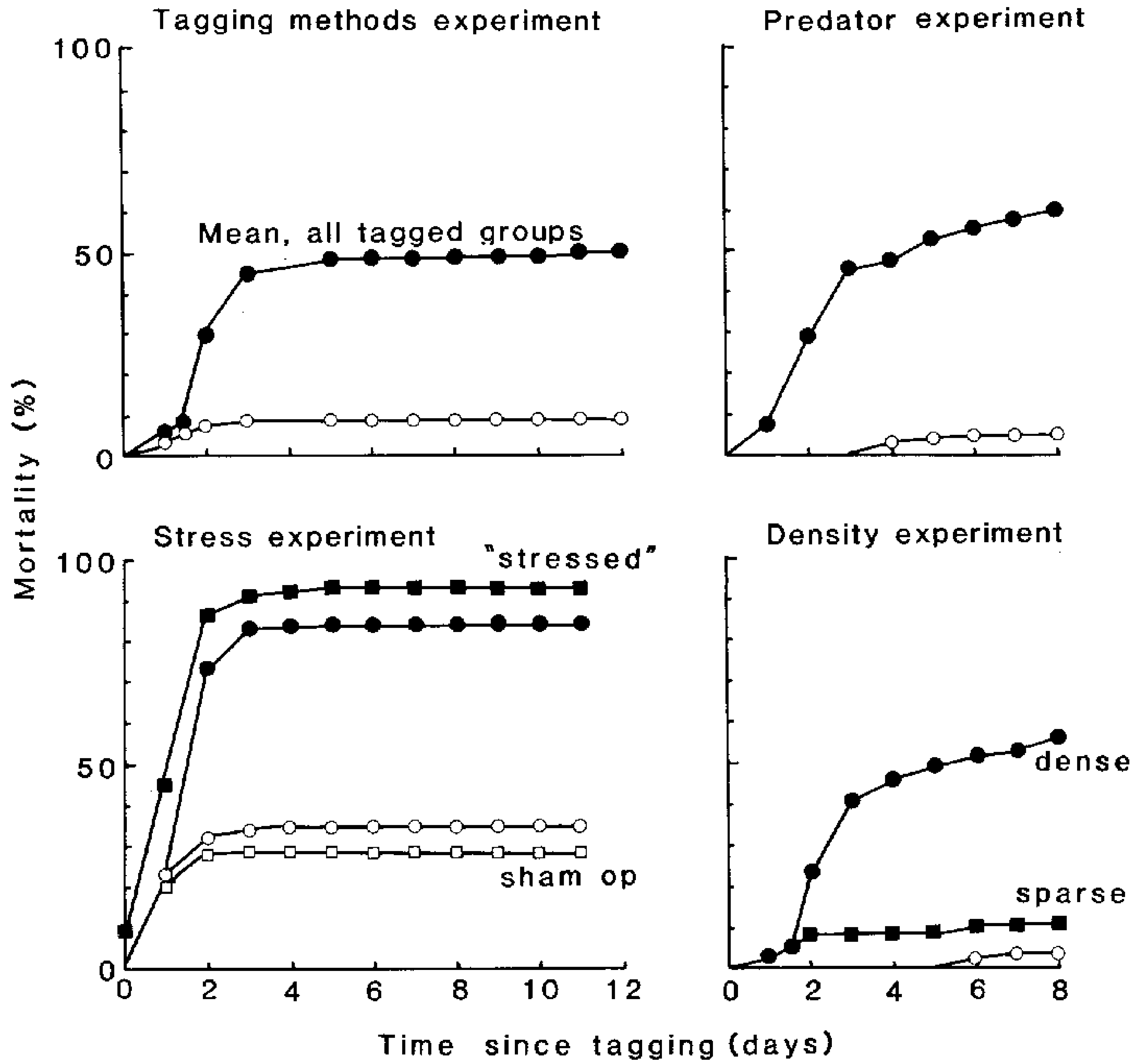

FIGURE 1.—*Cumulative mortalities of juvenile brown shrimp (bodies and free tags, where appropriate) in four tagging experiments. Filled symbols are tagged animals; open symbols are untagged. Lines are labelled where more than one tagged or untagged group per experiment is shown.*

ficiently rare that they could not alter any significant finding regardless of their actual fates. Of the 1,594 tags implanted in all experiments, 199 (12%) were recovered free of any animal remains. There was no evidence that animals who lost tags survived, because no live animal with a tag wound ever was recovered. In general, tagged animals suffered far greater mortality than their untagged counterparts (Table 1). Where such differential mortality occurred, it usually became significant on the second day after tagging (Fig. 1). Only for "stressed" animals in the stress experiment was that difference significant earlier ($G = 19.6$; $P < 0.01$: day 1).

Tagging Methods

Neither tagging method nor holding period had a significant effect on mortality, whereas the tagger effect was slight but significant: taggers 1 and 3 together produced lower mortality than taggers 2 and 4 combined (Table 2). The tagger effect was less pronounced for the Texas method–15-hour hold combination than for other treatments, accounting for a significant treatment–tagger–mortality interaction term.

Stress

Higher mortality among tagged animals was associated with the presence of the tag itself, rather than with any trauma inherent in the tagging procedure. Tagged animals in the stress experiment, regardless of condition prior to tagging, survived significantly less well than either animals handled identically except for the tagging step or animals pierced with tagging needles (Fig. 1). Sham-operated animals could be distinguished reliably for the first 3 days of

TABLE 2.—*Influence of tagger and tagging method on mortality of juvenile brown shrimp. Asterisks denote significance at* *P < 0.05 *or* **P < 0.01 (G *tests).*

Treatment	Tagger 1 Dead	Tagger 1 Live	Tagger 2 Dead	Tagger 2 Live	Tagger 3 Dead	Tagger 3 Live	Tagger 4 Dead	Tagger 4 Live	Total Dead	Total Live
Texas + 4 hours	24	25	19	28	37	13	24	24	104	90
Texas + 15 hours	24	25	21	28	25	25	25	24	95	102
Louisiana	36	14	25	25	26	22	16	32	103	93
Total	84	64	65	81	88	60	65	80	302	285

Hypothesis tested	df	G
Treatment × tagger independence	6	0.154
Treatment × mortality independence	3	1.278
Tagger × mortality independence	2	10.859*
(1 + 3) × (2 + 4) independence	(1)	(10.634)**
Treatment × tagger × mortality interaction	6	17.968**
Treatment × tagger × mortality independence	17	30.259*

observation (when most deaths occurred) by the hole in their cuticles. By the end of the experiment, however, the possibility that molting had obscured the needle hole required that survivors of sham-operated and handled-control groups be combined (Table 1). Selection for stressed animals hastened mortality and increased cumulative mortality, compared with unstressed tagged animals. A greater proportion of stressed animals had died on day 1 (G = 22.2; $P < 0.01$) and at the end of the experiment (G = 6.9; $P < 0.01$).

Predators

Tagged animals frequently were attacked by fish or by untagged shrimp immediately after release into the large tank. Attacks usually were directed at the tag-insertion sites. Tagged shrimp never were seen to make an attack, nor were untagged animals attacked during observations. Though tagged animals exhibited normal escape behavior when attacked, they frequently became visibly exhausted after a series of four or five such escapes. One-half of a tag was recovered on 6 February 1981 from the fecal strand of a fish used in the predator experiment, approximately 7 months after the conclusion of that experiment.

Density

The degree of conspecific crowding to which tagged animals were exposed had a marked effect on mortality. Tagged animals released into the larger compartment of tank 2 did not die with significantly higher frequency than untagged animals (G = 0.6; $P > 0.25$), whereas tagged animals released into the smaller compartment died with greater frequency than either crowded, untagged animals (G = 25.7; $P < 0.001$) or sparse, tagged animals (G = 48.1; $P < 0.001$).

Other Factors

Despite differences in the sex ratio and in the rate of mortality among groups of tagged animals from different experiments, there was no evidence that the sex of tagged animals influenced mortality (Table 3). Experiment and sex ratio were significantly nonindependent, pri-

TABLE 3.—*Effect of sex on mortality in tagged juvenile brown shrimp. Asterisks denote significance at* *P < 0.05 *or* **P < 0.01 (G *tests).*

Experiment	Live Males	Live Females	Dead Males	Dead Females
Tagging method	102	182	137	177
Stress	21	18	165	186
Predators	125	113	33	34

Hypothesis tested	df	G
Experiment × sex independence	3	11.467**
Experiment × mortality independence	3	304.003**
Sex × mortality independence	1	0.552
Sex × mortality × experiment interaction	3	5.858
Sex × mortality × experiment independence	10	321.880**

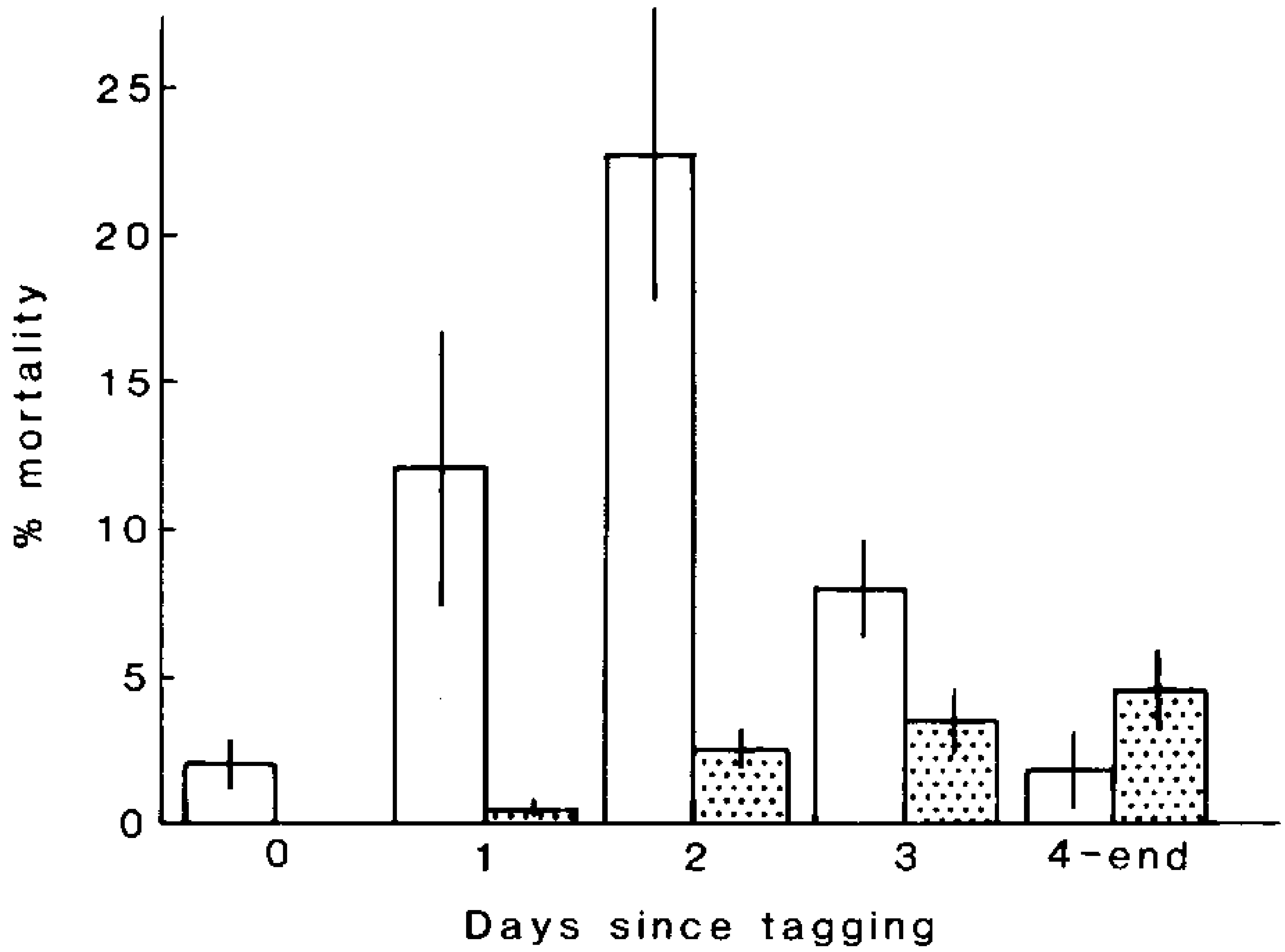

FIGURE 2.—*Mean daily mortality in groups of tagged juvenile brown shrimp attributed to tagged carcasses (open bars) and to free tags (stippled bars). Vertical bars show standard errors of the means of eight groups. Mortality after the third day of observation was summed.*

marily because females strongly predominated in the tagging-methods experiment compared with the other three experiments (G = 10.1). Mortality likewise depended on experiment, with most of that effect due to higher mortality in the stress experiment than in the others (G = 274).

Potential effects of animal size on tag-induced mortality were examined in the tagging-methods and predator experiments, for which sample sizes were large and mortalities of tagged animals were similar (Table 1). Initial tail lengths of animals that died or survived were separated into 8 or 9 classes to test abdomen length and survival for independence. In the tagging-methods experiment, the distributions of lengths for dead and live animals were indistinguishable (G = 3.2; 8 df; $P > 0.9$). For the predator experiment, however, mortality and size were significantly associated (G = 16.0; 7 df; $P < 0.05$), with survivors slightly larger (51.4 mm), on the average, than dead animals (49.7 mm). That effect was even more pronounced when only the 182 animals that died through the third day of the experiment were compared with the 155 survivors (G = 19.7; 7 df; $P < 0.01$).

Over all four experiments, tagged carcasses reached a maximum of 23% of the initial sample on day 2, whereas free tags peaked on day 3 (4%) and continued to account for significant mortality from day 4 until experiment termination (Fig. 2), when the tagged-carcass count had reached 0 in most experiments. Tags examined during the course of the experiments showed a steady accumulation of indentations and cuts (Fig. 3) that we interpret as marks left by chelate shrimp appendages. It is not known whether most damage was inflicted on tags while they were on animals or after they had become dislodged. In general, damage to tags occurred in all portions of their lengths but was most concentrated in the central region (Fig. 3).

Discussion

Under the conditions of these experiments, the presence of a streamer tag on juvenile brown shrimp clearly contributed to a markedly increased mortality risk, except where tagged animals were held with few untagged conspecifics at the lowest experimental density (10.9 animals/m^2). At all higher stocking densities, the difference between tagged and control mortality averaged 49.8% ± 7.5% (SD). Differential mortality usually began and peaked on the second morning following tagging, suggesting that the greatest increased risk of mortality occurred between 18 and 42 hours after tagging. Tag-associated mortality declined sharply after the third day of observations. Tag loss accounted for about one in eight inserted and reached a peak rate on day 3, one day later than the peak in recovery of tagged carcasses. It does not appear that counting free tags as deaths overestimated tag-associated mortality, because no live animal with a tag wound was ever recovered at the end of experiments. Free tags probably were removed from dead or moribund animals. There was no evidence that details of the tagging procedure influenced mortality, aside from a minor effect of tagger identity. This latter effect may have reflected differences in shrimp handling, in shrimp selection criteria, or in the quality of experimental animals available to the four test taggers. Of practical interest is that there appears to be little reason to prefer one tagging regime over another, at least regarding survival of tagged animals.

Biological factors appear to effect tag survival in some cases. Sex of tagged shrimp was apparently not a significant factor, which perhaps is not surprising in view of the immaturity of the animals tested here. Animals in poor condition with respect to previous anoxic stress (necrosis in abdominal muscles) began to die sooner after tagging than unstressed animals and survived somewhat less well by the end of the experiment, suggesting that elimination of animals with incipient necrotic foci may improve survival in field-tagging experiments. Finally, the results of the predator experiment suggest that larger animals may survive tagging somewhat better. A more conclusive test of that hypothesis could be made with shrimp of a broader size range.

The contribution of animal condition to post-tagging mortality remains essentially unquantified. Because the obviously stressed animals tagged in the stress experiment suffered disproportionate mortality, one might argue that the relatively high mortality among all tagged animals in our experiments was an artifact caused by the imposition of a minor additional stress associated with the tag on animals that were already in poor condition. If that were the case, then differential mortality might not have occurred if healthier animals had been tagged. While that hypothesis could explain why mortality was high in all groups used in the stress experiment, it does not explain the results of the predator and density experiments. Animals tagged in the latter two experiments demonstrated apparent good condition, by suffering low mortality (<0.1%/day) during 7 or 26 days of pre-tagging holding, yet they died significantly faster than controls after tagging. Better experimental estimation of the effect of animal condition on tag-related mortality will be possible when reliable and objective standards for assessing shrimp condition are developed.

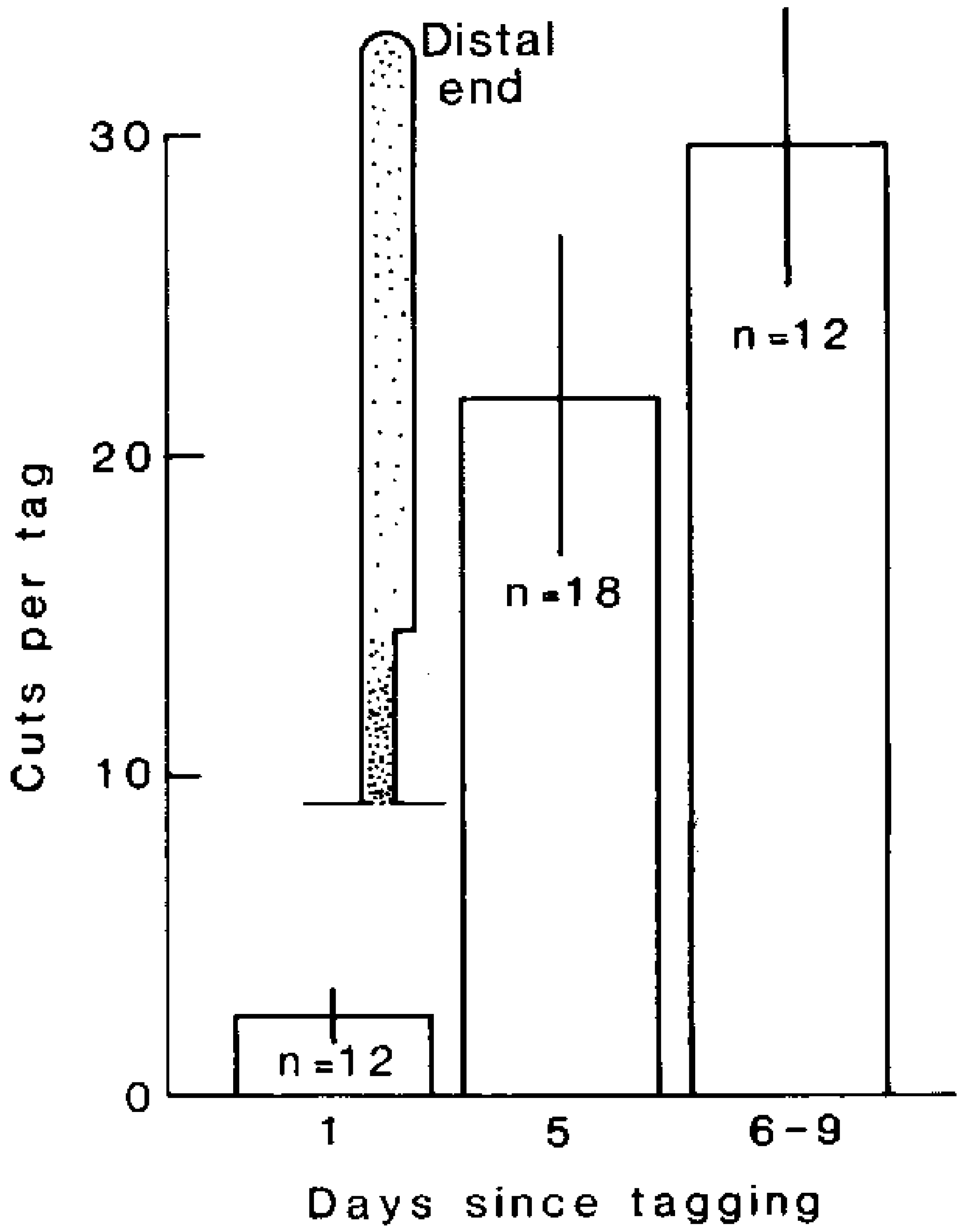

FIGURE 3.—*Average numbers of cuts per tag in tags recovered at various times from the tagging-methods experiment with juvenile brown shrimp. Tags recovered on day 1 were taken from carcasses; later tags were free-floating. Vertical lines are standard errors. Inset shows the spatial distribution of cuts on all tags from the day-5 sample on a scale drawing of half a tag, each dot representing the approximate location of a single cut.*

Though there are clearly many potential reasons why tagged animals may have died with greater frequency than untagged animals, an hypothesis that is consistent with all the results reported here is that tagged animals are preferentially attacked by other animals. Such attacks by fish and untagged shrimp were observed directly in the predator and density experiments. Though there may be several stimuli associated with tagged animals (altered behavior, for example) that could provoke attacks, our observations that attacks were directed at the free portion of the streamer tags and that tags steadily accumulated marks produced by manipulation suggest that those stimuli are provided by the tag itself. That interpretation is consistent with our finding (stress experiment) that animals that did not carry tags, but were otherwise handled and wounded like tagged animals, experienced relatively low mortality rates, and that tagged animals exposed to the lowest densities of untagged conspecifics (2.2 animals/m^2) suffered the lowest rates of mortality (density experiment). Though attacks evoked by sounds or odors associated with tagged animals may have contributed to differential mortality, the attackers observed in the predator and density experiments often swam directly and immediately toward tagged victims more than 1 m away, suggesting that visual stimuli are at least sufficient to evoke attacks. None of the potential attackers in these experiments were capable of killing tagged shrimp in a single attack. It seems likely, however, that repeated attacks directed at tags evoked a series of escape behaviors in the attacked animal that eventually exhausted the escaping animal, rendering it less efficient at avoiding subsequent attackers. If the above hypothesis is correct, the reduction in tag-related mortality after 3 days may be due to improved ability of tagged animals to avoid attacks by burrowing or to habituation by attackers to tag-associated stimuli.

Our results agree with those of Farmer and Al-Attar (1979), who evaluated several tagging methods for *Penaeus semisulcatus* in aquarium trials. In the first of two trials with Floy streamer tags, they placed 50 tagged and untagged animals in each of three aquaria and found significantly higher mortality (46.7%) among tagged animals than among untagged ones (16.0%) after 2 weeks. In a second trial, 100 tagged and 100 untagged animals were placed in separate aquaria. Only tagged animals had died after 14 days, though cumulative mortality (13%) was lower than for tagged animals in the first trial. Farmer and Al-Attar (1979) attributed this reduction in mortality to improvement in tagger skill, though, based on our results, we propose that attacks by untagged animals on tagged animals in the first trial is a more likely explanation. Farmer and Al-Attar themselves used the latter hypothesis for another experiment to explain why shrimp marked with subcutaneous pigment suffered high mortality (compared with controls) only when held with unmarked conspecifics.

Our conclusions contrast sharply with those of Marullo et al. (1976) and Johnson (1981), who found no increased mortality attributable to streamer tags in aquarium or pond studies. Differences in experimental conditions could fully account for that apparent disagreement. Aquarium trials were performed with 50 or fewer animals per treatment group in small tanks (<1 m^2), and brown shrimp was used in only one of those three trials (Marullo et al. 1976). Small tanks inhibit many normal shrimp behaviors, including the escape reflex and swimming. If behavioral interactions of animals contribute to tag-induced mortality, as we contend, then comparisons between our results and those of some earlier aquarium trials may not be meaningful. Even so, Marullo et al. (1976) report that all five deaths in a sample of 32 tagged white shrimp *Penaeus setiferus* occurred during the first 3 days of a 30-day trial, a finding consistent with the mortality pattern we describe.

Pond studies were conducted in 1,000 m^2 earthen ponds under conditions that differed substantially from those in the present study. With 500 animals per pond, animal densities were 0.5 animals/m^2, far below the densities at which we could detect tag-induced mortality. Neither pond study involved brown shrimp. There were also difficulties with interpretation of pond data. In the earlier study (Marullo et al. 1976), mortality of tagged animals significantly exceeded control mortality in one pond ($G = 27.95$; $P < 0.01$: our calculations) and was significantly lower than control mortality in the second pond ($G = 17.8$; $P < 0.01$). A more conservative interpretation of those results might be that conditions in the two ponds differed so much with respect to the effects of tags that an overall conclusion was unwarranted. In the later study (Johnson 1981), unexplained loss of tags was uniformly high in all trials (25–48%), though counts of confirmed survivors after 30 days did not show differences in survivorship between tagged and untagged animals in the presence or absence of predaceous fish.

The most important difference between conditions in mud-bottom ponds and the tanks used for the present study may be water clarity. Recent turbidity readings at the Baytown, Texas ponds used in the 1976 study (recorded at the same season) show that visibility is variable but less than 50 cm. Secchi disc readings of 50 cm or less were representative for the Corpus Christi, Texas ponds during Johnson's research. In contrast, water was exceptionally clear throughout our studies with estimated underwater visibilities of at least 5 m. If tags are visual attractants for predators, then one might expect that the resulting effects on mortality would depend strongly on water clarity.

Our suggestion that attacks directed at tags contribute to higher mortality of tagged animals points to another potential source of difference between the present results and those of Marullo et al. (1976). In those experiments, tags were either unpigmented or dyed red. Because marine crustaceans do not appear to have visual pigments sensitive to red light (Waterman 1961), it is probable that neither unpigmented nor red tags were perceived by shrimp as bright objects. The green tags used in the present study, however, reflect light of wavelengths near the sensitivity maximum for many crustaceans (Waterman 1961). The potential influence of tag color on tag-related mortality is clearly a subject of practical interest for future investigations.

Extension of these results to field-tagging efforts are speculative. Though efforts were made to observe test animals in large tanks and to simulate natural substrate, it remains possible that our results represent artifacts introduced by abnormal crowding or confinement. Our findings are consistent, however, with the predation hypothesis advanced by Cody and Avent (1980) to explain poor tag recoveries. In summary, our results suggest that neither the presence of a steamer tag nor the stress involved during its insertion have significant direct effects on mortality, but that under certain conditions tags may indirectly cause mortality by attracting other animals. In view of similar results with subcutaneous pigment marks (Farmer and Al-Attar 1979), it seems likely that many, perhaps all, tags or marks that make shrimp more conspicuous to humans also may make shrimp more conspicuous to other animals. For that reason, steamer tags with demonstrably smaller direct effects on mortality may still be the best choice among available tags.

Acknowledgments

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References

Cody, T. J., and R. M. Avent. 1980. Mark-recapture studies of penaeid shrimp in Texas, 1978–1979. Texas Parks and Wildlife Department Management Data Series 14, Austin, Texas, USA.

Farmer, A. S. D., and M. H. Al-Attar. 1979. Results of shrimp marking programmes in Kuwait. (Proceedings of an international shrimp releasing, marking and recruitment workshop, Ryad, Kuwait.) Kuwait Bulletin of Marine Science 1:1–32.

Johnson, M. F. 1981. Shrimp mark-release investigations, volume 2. *In* W. B. Jackson and E. P. Wilkens, editors. Shrimp and redfish studies; Bryan Mound disposal site of Freeport, Texas, 1979–1981. NOAA (National Oceanic and Atmospheric Administration) Technical Memorandum NMFS (National Marine Fisheries Service)-SEFC-66, Washington, District of Columbia, USA.

Marullo, F., D. A. Emiliani, C. W. Caillouet, and S. H. Clark. 1976. A vinyl streamer tag for shrimp (*Penaeus* spp.). Transactions of the American Fisheries Society 105:658–663.

Rigdon, R. H., and K. N. Baxter. 1970. Spontaneous necroses in muscles of brown shrimp, *Penaeus aztecus* Ives. Transactions of the American Fisheries Society 99:583–587.

Sokal, R. R., and F. J. Rohlf. 1969. Biometry. W. H. Freeman, San Francisco, California, USA.

Waterman, T. H. 1961. Light sensitivity and vision. Pages 1–64 *in* T. H. Waterman, editor. The physiology of Crustacea. Academic Press, New York, New York, USA.